THE

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All communications should be addressed to the Editor.

No. 119. NOVEMBER, 1920. Vol. XXIV.

Notices of the Royal Aëronautical Society.

Election of Members.

The following members were elected in the various grades as shown at a Council meeting held on October 19th:—

Fellows.—Lieut.-Col. W. A. Bristow, the Rt. Hon. Lord Weir of Eastwood.

Associate Fellows.—Flight Lieut. J. C. Atkinson, J. W. Copley, W. E. Dumbrill, B.Sc., J. E. Jones, B.Sc., H. Rogerson, Capt. C. G. Sturt, A.F.C., Capt. L. J. Wackett, L. J. Wood.

Students.—H. R. Cox, S. H. Evans, P. T. Griffith, J. P. Rathbone, G. M. Scott, F. G. Whitmore, Chaucer Wood.

Members.—W. J. Adderley, Flight Lieut. C. Russell Cox, R.A.F., Lieut. C. G. Little, U.S.N.

Associate Members.—E. P. Appleby, Flight Lieut. C. Hilton Keith, R.A.F., A. Ruthven-Stuart, Lieut.-Col. H. Laws Webb, F. J. McConnel.

Foreign Member.—Lieut. H. Sorensen, Danish R.N.

Scottish Branch.

Fellows.—Prof. A. H. Gibson, M.Inst.C.E., F.R.S.E.

Associate Fellows.—A. E. Marsden, H. E. Yarrow, C.B.E., M.Inst.C.E.

Associate Members.—A. M. Kay, R. G. Millar, A. Page, T. H. Storer.

Student.—A. Cairns.

Lectures.

The following papers will be read during the month of November, in each case in the Theatre of the Royal Society of Arts:—

November 4th.—"The Human Machine in Relation to Flying," by Wing Commander M. Flack. Sir Humphrey Rolleston, K.C.B., M.D., F.R.C.P., will take the chair at 5.30 p.m.

November 18th.—"The Problem of the Helicopter," by M. Louis Damblanc, the French Consulting Engineer, who is carrying out experiments with direct-lift machines on behalf of the French Government. This meeting will commence at 5 p.m.

The papers by Mr. Irving and Mr. Fage have been postponed to a later date.

The papers during December will be as follows :—

December 2nd.—" Airship Piloting," by Major G. H. Scott, C.B.E., A.F.C.

,, —" Airship Mooring," by Flight Lieut. F. L. C. Butcher, R.A.F.

December 18th.—" Possible Development in Aircraft Engines," by Mr. H. Ricardo.

,, —" The Instalment of Aeroplane Engines," by Mr. A. J. Rowledge.

Scottish Branch.

The following course of lectures has been arranged to be given to the Students of Glasgow University :—

November 1st.—" Aircraft : General Design," by Squadron Leader J. S. Buchanan.

November 2nd.—" Aircraft : Details of Construction," by Squadron Leader J. S. Buchanan.

November 15th.—" The Technique of Flight," by Squadron Leader R. M. Hill.

November 16th.—" The Technique of Flight," by Squadron Leader R. M. Hill (second lecture).

November 22nd.—" Airships : General Principles," by Mr. J. L. Bartlett.

November 23rd.—" Rigid Airships : Design and Materials," by Mr. J. L. Bartlett.

The address of the Scottish Branch is Blythswood Square (entrance in 4, Jane Street), Glasgow.

Cambridge University Aeronautical Society.

The first Session of the Society successfully terminated in March last with some 130 undergraduate and 20 honorary members on its roll. No lectures have been given during the summer months, but in May over 80 members visited the Royal Airship Works, Cardington, Bedford, and some considerable number were to be found at Martlesham during the competitions.

H.R.H. the Duke of York has graciously consented to become the Patron of the Society. As His Royal Highness, besides being a pilot, has also been up at Cambridge, the Society feels itself greatly honoured to have as a patron a member of the Royal Family who is so intimately connected with its activities.

The following is the syllabus for the present term :—

Nov. 3rd.—" Spins," by Mr. H. Glauert, B.A., F.R.Aë.S.

Nov. 10th.—Public Meeting with the Air League of the British Empire. Major-General Rt. Hon. J. E. B. Seely, C.M.G., D.S.O., M.P., " Air Supremacy."

Nov. 17th.—" Communication with Aircraft," by Major J. Erskine Murray, D.Sc.

Nov. 24th.—" Rigid Airships," by Mr. C. I. R. Campbell, O.B.E., A.F.R.Aë.S.

Dec. 1st.—" Aeroplane Design, some Present and Future Possibilities," by Capt. F. S. Barnwell, O.B.E., F.R.Aë.S.

Visit to H.M. Airship Station, Pulham. (Date to be announced.)

All meetings commence at 8.30 p.m. Further particulars will be found in the weekly notices.

Annual Dinner.

The Annual Dinner will take place in the Connaught Rooms, at 7.0 for 7.30 p.m., on Wednesday, November 17th. The Right Hon. Lord Weir of Eastwood, President of the Society, will take the chair. Tickets (price one guinea each,

exclusive of wine) may be obtained from the Secretary, and members are invited to bring guests. Ladies will be welcomed.

Official Abbreviations.

The Society has been informed by the Home Office that it is now authorised to adopt the use of the prefix "Royal" in the abbreviations for Fellows and Associate Fellows. These members are therefore entitled to use the letters "F.R.Aë.S." and "A.F.R.Aë.S." respectively after their names, and these forms will supersede those previously used in all official communications.

Library.

The following books have been received and placed in the Library:—"The Struggle in the Air 1914-1918," Charles C. Turner; "Design of Aeroplane Engines," John Wallace; "English-French Aero Dictionary," Leonard Henslowe.

Early Correspondence.

The Secretary's researches in old correspondence in the office have revealed a large number of autograph letters from early pioneers and others, many of which are of extreme interest as bearing upon the history of the Society. Among them are letters from Sir Edwin Arnold (as Member of Council), Henry Coxwell, Thomas Moy, Sir Hiram Maxim, Octave Chanute, Wilbur and Orville Wright, Robert Cocking, Santos Dumont, Major Moedebeck, Major Parseval, Count Zeppelin, Percy Pilcher, Lawrence Hargrave, and many others.

Air Mail.

It has been decided that in future letters will be sent by Air Mail in the case of all correspondence to countries which are so served. It is felt that if all members of the Society would follow the same course, practical assistance would be given to the development of commercial aviation.

Army Quarterly.

The attention of members is called to a new quarterly publication, the "Army Review," which has taken the place of the "United Services Magazine." The first number contains an article by Wing Commander Chamier on the "Aircraft Co-operation with Infantry," and the whole publication is of an important nature.

Arrangements for the Month.

Nov. 3.—Cambridge University Aeronautical Society, "Spins," by H. Glauert, Fellow, at 8.30 p.m.

,, 4.—"The Human Machine in Relation to Flying," by Wing Comdr. M. Flack, at the Royal Society of Arts, at 5.30 p.m. Sir Humphrey Rolleston, K.C.B., M.D., F.R.C.P., in the chair.

,, 4.—"Case-Hardened Steels and some Defects met with during Inspection," by Capt. W. A. Thain, at Sheffield University, at 5.15 p.m.

,, 10.—Cambridge University Aeronautical Society, Joint Meeting with Air League of the British Empire. "Air Supremacy," by Major-General Rt. Hon. J. E. B. Seely, C.M.G., D.S.O., M.P., at 8.30 p.m.

,, 14.—Air Commodore Brooke-Popham, Chairman, lecturing to the Scottish Branch at Glasgow.

,, 16.—At the Society's offices, Candidates' Qualifications Committee at 3.30 p.m. Lectures and Publications Committee at 4.0 p.m. Council at 5 p.m.

Nov. 17.—Annual Dinner at the Connaught Rooms, at 7.0 for 7.30 p.m.

,, 17.—Cambridge University Aeronautical Society, "Communication with Aircraft," by Major Erskine Murray, D.Sc.

,, 18.—"The Problem of the Helicopter," by M. Louis Damblanc, Ingénieur Conseil, at the Royal Society of Arts, at 5.0 p.m.

,, 24.—Cambridge University Aeronautical Society, "Rigid Airships," by C. I. R. Campbell, O.B.E., M.I.N.A., Associate Fellow.

W. LOCKWOOD MARSH,
Secretary.

PAPER TO BE READ BY WING COMMANDER M. W. FLACK, C.B.E., R.A.F., ON THURSDAY, NOVEMBER 4th, 1920.

THE HUMAN MACHINE IN RELATION TO FLYING.

SYNOPSIS.

The Body Bellows.

The importance of adequate intake and output.
The correct working of the bellows.
The effects of altitude.
The ill effects of partial failure of the bellows.

The Circulatory Pumps.

The importance of an efficient pump, especially as regards the maintenance of pressure between the strokes.
The accessory pumping mechanisms.
Results of insufficiency of the accessory mechanisms.

The Muscular Engines.

How they work and the importance of efficient performance.

The Co-ordinating Mechanism.

The human machine provides the co-ordinating mechanism for the aeroplane.
The importance of vision, hearing, touch and "sense of balance" in the co-ordination of the human machine.
Some hints on how to keep the machine in efficient order.

PROCEEDINGS.

FIRST MEETING, 56th SESSION.

The First Meeting of the Fifty-sixth Session was held in the Hall of the Royal Society of Arts, London, on Thursday, October 7th, 1920, the Right Hon. A. H. Illingworth (Postmaster-General) occupying the chair.

Brig.-Gen. R. K. BAGNALL-WILD said he had pleasure in resigning the Chairmanship of the Society in favour of Air Commodore Brooke-Popham, who was well-known to the members and under whom he was sure this next year's work would be ably conducted.

Air Commodore H. R. M. BROOKE-POPHAM said he thought it a great honour to be asked to be Chairman of the Royal Aeronautical Society this year, and he would do his best to deserve the honour. He looked upon this particular lecture as in some degree historic, because, he thought, it was the first time upon which one of our great Ministers of State, other than the Air Minister, had honoured the Society by taking the Chair, and in welcoming Mr. Illingworth there, he was sure he might say they saw in his presence not only a sign of the great interest he took in aviation, but good grounds for hope that he had every intention of making full use of the means now at his disposal for perfecting our already excellent postal service.

The CHAIRMAN (Mr. Illingworth) thanked Air Commodore Brooke-Popham for his kind words, and said he was sure they would do their best to please the public in that office over which he presided at present. He did not think it was necessary for him to make any long harangue or speech in introducing Sir Frederick Sykes. He was so well-known for the great services he had performed during the war and his brilliant career in the Forces that he would merely ask him to be good enough now to read his Paper.

Major-General Sir F. H. SYKES, G.B.E., K.C.B., C.M.G., Controller-General of Civil Aviation, then delivered the following Lecture :—

CIVIL AVIATION.

INTRODUCTION.

Aviation is divided into two main branches ; *civil aviation*, comprising the two industries—aircraft construction and civilian air transport—which together aim at the acceleration of intercommunication and the expansion of trade by means of air transport ; and *service aviation*, the ultimate object of which is direct defence.

The two branches are independent, yet closely allied ; independent in that commercial and fighting types of machine and the problems presented in their development continually tend to diverge ; closely allied, because in future the actual cadres which compose the country's Service air forces in peace can only be augmented in war emergency by a reserve of men (who might easily be placed on a volunteer basis), material and experience in construction and design afforded by commercial aviation.

It is evident, however, that commercial aviation cannot be fostered merely as a reserve for the country's air forces. Its test must be that of commercial success. Not yet two years have elapsed since the Armistice was signed and already numerous experiments are being conducted in the operation of air services in different parts of the world, and their initial results have been such that their number shows no sign of diminution.

Civil aircraft are of great use in the high speed carriage of mails, small valuable goods, passengers, and for sundry purposes, such as mapping and survey work, but mails—at all events for the time being—are the basis upon which commercial aviation, both from the constructional and transport sides, must develop.

It is the purpose of this paper to illustrate the growth of and work carried out by air mail, passenger and goods services as they exist at present at home, in the Empire, and abroad; to investigate some of the factors contributing to their success; and to put forward some suggestions as to future development.

I. GROWTH AND PRESENT POSITION OF AIR MAIL, PASSENGER AND GOODS SERVICES.

(a) United Kingdom—Internal.

There are, as yet, no internal air services in the United Kingdom—a fact chiefly due to the comparatively short distances to be covered; the excellence of existing communications; and the uncertainty of meteorological conditions.

I believe, however, that Messrs. Beardmore intend to start an experimental service between London and Glasgow in the near future, and I hope this venture will succeed, and will be the precursor of many others in this country.

(b) United Kingdom—Continent.

There are at present three direct routes from England to the Continent, *i.e.*, from London to Paris, Brussels and Amsterdam. The first regular daily service to Paris was inaugurated by the Aircraft Transport and Travel Company in August, 1919. In May, 1920, a double service was started by the same company, machines leaving the State-owned aerodrome at Croydon morning and afternoon. This company has the contract for the carriage of mails to Paris. The Instone Company and Air Post of Banks have also established services between London and Paris. A fourth service is operated by Messrs. Handley Page from their private aerodrome at Cricklewood, where Customs facilities are provided.

Correspondence for Egypt, India and the East, if posted in time for air mails to Paris on Friday morning, will secure connection with the ordinary mail despatched from London on the previous evening.

The London-Brussels mail service is operated by Messrs. Handley Page. An additional advantage of this service is that it affords an acceleration of at least 24 hours in delivery of letters by ordinary mail to countries beyond Belgium.

The Handley Page Company also holds the contract for the carriage of mails between London and Amsterdam, which is the junction for air lines to Germany and Scandinavia. The Aircraft Transport and Travel Company also conducts a service on this route.

Apart from their value in advancing the development of general aviation, I think you will agree that these services have very considerable actual value for the public, but it will be seen from the attached table that though the mails are growing in volume, the public response is still much smaller than it should be.

I think it would repay any of those present who have not yet done so to visit the air port of Croydon. It is only in a very experimental stage, but we believe it to be the best equipped civil aviation aerodrome in the world.

I will now give you a brief description of the foreign air services actually in operation, only alluding to a few of the more important projected lines.

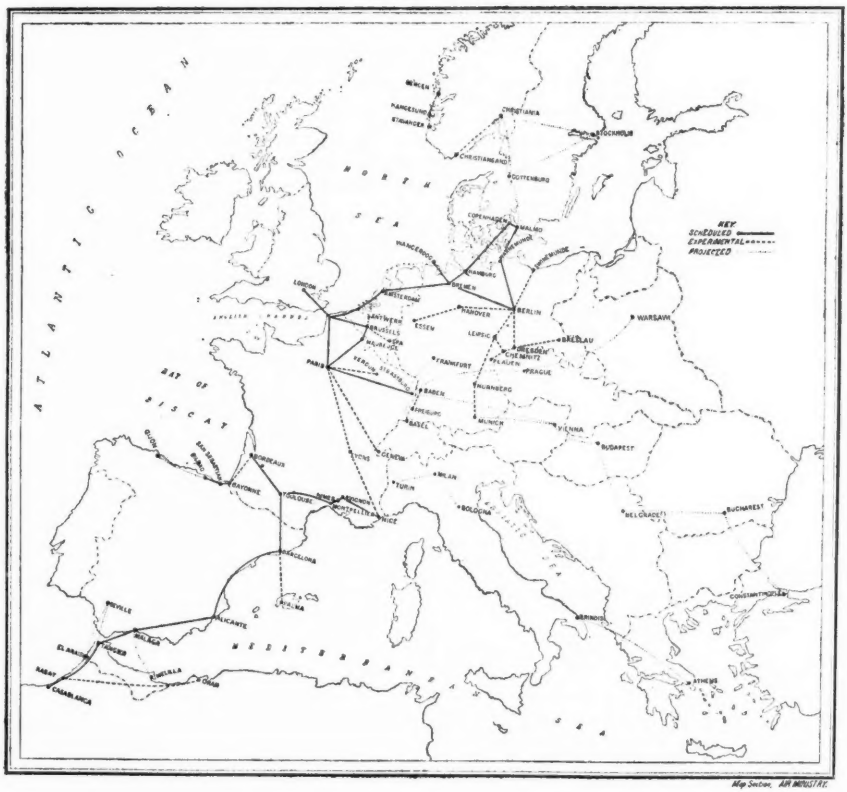
(c) Foreign.

(1) *France.*—French air transport companies assisted by the Government subsidy scheme, which I shall deal with later, have established a number of

services. There are four between Paris and London, two scheduled to run daily, the others spasmodic, a service from Paris to Brussels, and one from Bordeaux to Nice.

In conjunction with the Spanish authorities, a service is operated by a French company between Bayonne and Bilbao, and its extension northwards to Bordeaux and westwards to Gijon is expected shortly.

EUROPEAN AIR SERVICES.



Map Section, AIR MINISTRY.

The French air authorities have been swift to appreciate the advantages of, and to encourage, air communication between the mother country and her North African colonies, with the result that the Latecoere Company has for several months operated a tri-weekly service between Toulouse, Tangiers and Rabat (recently extended to Casablanca). By an arrangement with the Spanish postal authorities, the Latecoere Company is responsible for the carriage of mails between Alicante and Malaga. A subsidiary service is conducted five times a week between Malaga and Casablanca.

The establishment of an airship service between Paris, Marseilles and Morocco is proposed.

An important scheme is now under discussion for the inauguration of an air mail service between Paris and Southern Europe, and an agreement is believed to have been concluded between the French Post Office and the Czecho-Slovak and

Polish Governments. The first section of this route between Paris and Strassburg is already open, and extensions are projected from Strassburg to Warsaw, and from Strassburg to Vienna, Budapest, Belgrade, Bucharest, and Constantinople. The Franco-Rumanian Company which is to operate these lines, will according to the agreement receive a subsidy from the Czecho-Slovak and Polish Governments.

(2) *Belgium.*—A Belgian Company, the National Syndicate for the Study of Aerial Transport, which is responsible for most civil aviation schemes in Belgium, is operating an air mail and passenger service from Brussels to London, and also conducts two small and irregular services from Brussels to Spa and Antwerp.

The Syndicate is responsible for an enterprising scheme in the Belgian Congo, where it has initiated the "Ligne Aerienne Roi Albert" between Kinshasha and Stanleyville, the first section of which is already open.

(3) *Holland.*—The Royal Dutch Aerial Transport Company, which holds a mail contract from the Dutch Government, works in conjunction with the Air Transport and Travel Company. It has also made an arrangement with a German company by which air mails are despatched to Berlin.

The Dutch are also interested in establishing air services in the Dutch East Indies. Any experiment they may make will be helpful for the India-Australia route and also interesting to us as we are faced by similar problems in the West Indies.

(4) *Germany.*—German effort has been hampered by the terms of the Peace Treaty, and German activity has been confined to the promotion of air transport companies, chiefly for propaganda work, and to a considerable amount of what will probably prove to be valuable research work. Two companies, the Deutsche Luftredei and, in conjunction with Scandinavian and Dutch interests, the Sablatnig, have, however, quite recently initiated an air service which may prove to be the germ of a future North European system of air routes. This line runs from Copenhagen to Hamburg, Bremen and Amsterdam, where it connects with the Handley Page mail service. A second line runs from Copenhagen to Malmö, Warnemünde and Berlin. There is a connecting line with an extension to the seaside resort at Wangeroog. These services are run daily.

(5) *Norway.*—A fairly successful experimental air mail service was carried out between Christiania and Christiansand by Government machines during the summer months, in addition to which an air mail service, employing four British flying boats and two German seaplanes, has been running between Stavangar and Bergen, via Haugesund, as the result of three months' contract between the Norske Luftrederei and the Norwegian Post Office.

(6) *The United States.*—A particularly interesting experiment in the carriage of mails by air is being made by the United States Post Office, which owns, operates, and is entirely responsible for the machines used in this service. The original lines inaugurated in 1918 were from New York to Washington and from New York to Cleveland and Chicago. The Chicago line has now been extended to Minneapolis and St. Paul, Omaha and St. Louis, and further extensions are contemplated. An appropriation of $1,250,000 to be used for the establishment of a service from New York to San Francisco was passed by Congress this year.

According to the U.S. Postmaster-General, between May 15th, 1918, and January, 1920, these services operated over 473,210 miles, carried 22,254,400 letters, thus advancing delivery on an average by sixteen hours, and achieved a performance of 91.49 per cent.

The costs work out at slightly less than $1 per mile, but the accounts do not clearly state whether this figure includes the important item of depreciation.

(d) British Dominions and Colonies.

Although, with one exception, no regular commercial air lines have yet materialised in the Dominions or Colonies, I think that something should be said of the work which they are doing, since the success of future services will depend to a great extent upon the preparation of sound schemes of ground organisation.

Canada, India and New Zealand have instituted Air Boards. The functions of the Canadian Board are similar to those of the Air Council in Great Britain.

All the Canadian Government air stations will be available for commercial traffic, and the Superintendent of Flying Operations, the member of the Board responsible for all civil aviation undertaken by the Government, has disposed of a number of hangars to municipalities to encourage and assist the establishment of public air ports.

The Board is experimenting in photo-topographical surveying in the province of Quebec and in the Ottawa and Toronto districts, and the preliminary survey of a proposed air route between Winnipeg and Sudbury in Ontario has been carried out.

An important feature of the Canadian scheme is that persons taking out civilian certificates at the same time agree to become members of the Canadian Air Militia and to attend instruction courses.

The Indian Board, which is under the administration of the Department of Commerce and Industry, has decided upon the provision of aerodromes on the Calcutta-Bombay-Delhi-Karachi, Karachi-Bombay and Calcutta-Rangoon routes.

The relatively equitable weather conditions of India, its size, and the volume of potential air traffic, should lead to the steady development of commercial air transport.

There is no doubt that the progressive element of the commercial world in India recognises the advantages of, and would welcome, the establishment of air transport services on a commercial basis.

The New Zealand Board includes representatives of the Departments of Land and Survey, Public Works and Post Office, and its functions are to consider and advise on all questions connected with aviation; to maintain touch with the British Air Ministry; and to keep pace with modern developments throughout the world.

Australia possesses an Air Service Committee; the South African Government is examining the whole question of aviation; and the interest of both Dominions has been stimulated by the great demonstration flights from England. I shall touch later on a project for an air service from Melbourne.

I mentioned that there was one exception to the lack of air services in the Dominions and Colonies. In the spring of this year the Bermuda and West Atlantic Aviation Company inaugurated a service in the Bermudas with Supermarine flying boats and Avro seaplanes, and more extensive schemes, which I shall deal with later, are under consideration in the West Indies.

II. FACTORS CONTRIBUTING TO SUCCESSFUL AIR SERVICES.

(a) Safety and Reliability.

To those who remember that it is less than two years since the end of the war, the growth outlined above may seem considerable; to others the network of air lines which we hope some day to see may still seem a long way off. Both views contain a measure of truth. Though at the end of the war we had a very large military air service and the leading constructional industry, there was nothing at all in the shape of a single civil air transport concern. The services so far inaugurated are still in an experimental stage, and their success, viz., their

capacity to produce an adequate return for capital expenditure, can only be realised by carrying out continual improvements.

I therefore now propose to consider what is being done and what it is hoped to accomplish in the near future towards this.

Our watchwords must be safety and reliability. Without these neither can the public be expected to utilise air transport, nor is there any inducement to surrender mails and other freight for carriage by aeroplane.

Since the Armistice the Accidents Branch of the Civil Aviation Department has conducted investigations into all serious accidents brought to their notice, and reports on the causes of such accidents, enabling any experience gained to be given general application; and now the Air Navigation Bill before Parliament provides for obligatory notification of accidents involving serious injury to occupants, or serious structural damage to aircraft, and power to summon witnesses and publish reports.

Every effort is, in addition, made to reduce the number of accidents which may arise from the personal factor by periodical medical examination of pilots.

Apart from weather, the safety of an aircraft depends largely upon its engines, their installation and accessibility and their accessories, including the petrol, oil, water and ignition systems. During the earlier stages of the war the average life of an engine before complete overhaul was necessary was, of stationary engines, from 50 to 60 hours, and of rotary engines, about 15 hours. To-day, these figures stand at 200 hours and upwards and from 50 to 60 hours respectively.

Increase in reliability may also be furthered, either (1) by using a very light power plant per horse-power, run normally at about half its maximum, and (2) by using a plant of greater weight, more solid construction, and greater efficiency, running at nearly its full horse-power. The former method is more expensive in primary cost and upkeep, but allows of higher performance and provides reserve horse power for emergencies; the latter is cheaper but involves a certain risk owing to lack of surplus power in emergency.

The safety devices which are of special utility for commercial machines are those which seek to overcome the possibility of fire, and those, such as devices for varying the lift of the wings, that seek to lower the landing speed and thus decrease the dangers attendant on forced landings. Another important factor is the careful and efficient testing of material. The danger of fire in the air is very remote, but fire may occur in case of a bad crash. I think that is being overcome.

Incidentally I would strongly urge that the present general system of starting the engine by turning the propeller by hand is entirely antiquated and should no longer be tolerated. It is answerable for approximately 10 per cent. of Service accidents.

The all-metal machine affords certain advantages in obtaining safety and durability, especially in tropical climates. A British example of all-metal construction was recently exhibited at the Olympia Exhibition by Messrs. Short Brothers, but in this respect the Germans have taken the lead. The Junker machine, which has high-lift wings built on the cantilever principle without external bracing, has made several successful flights in America and Sweden. This important development is not being lost sight of in this country.

Safety and reliability secured, we must increase the speed of aircraft. The root of the commercial air transport problem is to discover the best compromise between speed and weight-carrying capacity. Any improvement in wing design naturally improves performance in this direction, and it is to wing efficiency that British designers are paying special attention. The high-lift wing favoured in Germany sacrifices total efficiency to lift; in England experiments are being made to overcome the difficulty (1) by providing a device as in the cases of the Handley

Page and Fairey wings, which enables the lift to be increased, as in starting and landing, without the efficiency of the wing in normal flight being impaired; and (2) by so designing the wing as to give high lift without the consequent loss of efficiency, as exemplified by the "Alula" wing. In addition to wing design, we must continue to give deep consideration to the development of some form of helicopter, a device not only invaluable for the machine itself but also for many other reasons, such as the reduction of the size of aerodromes, and the possibility of placing them nearer to centres of population.

Other factors making for safety, reliability and regularity are the timely issue of weather forecasts, devices for "direction finding" by wireless in cloudy and misty weather, and last, but by no means least, the human element, the efficiency of the pilot and ground engineer.

(b) **Use of Different Types of Aircraft.**

Each type of aircraft possesses some advantages which the other lacks. Thus it is within the power of the modern airship to fly to Egypt and back without landing with a load of twenty tons; it can fly day and night, and is not so handicapped by fog and bad visibility; it possesses six engines on which running repairs can be made in the air. The aeroplane, on the other hand, has a much greater speed, and, even if the mooring of airships to a mast proves effective, will probably always be much more easily landed, housed and overhauled. You all, probably, know of the experiment in mooring airships to a mast. This will have many advantages and overcome many of the present difficulties. The problem, however, is not one of rivalry, but of co-operation. The heavier-than-air craft is undoubtedly the best type for journeys which can be undertaken within the hours of daylight, the airship for journeys of such a length as to involve day and night flying.

Types of aircraft, the development of which is of particular importance to us as an island State, are the seaplane, flying boat and amphibian. It is not unlikely, in my opinion, that in the future the aeroplane, the seaplane and the flying boat will yield much of their sphere to the amphibian, early types of which have recently undergone successful trials in the Air Ministry Competitions.

As mail, goods or passenger services extend their radius of operation over country possessing variable characteristics, the type of aircraft best adapted to each section of the route has to be considered and a system of relays established. Differentiation of types is required in accordance not only with the distance and natural characteristics of the route, but also with the nature of the freight carried. Whether aeroplane or airship, seaplane or amphibian is used, each will gradually tend to be sub-divided into mail, goods and passenger carriers. The special requirements for the first are speed; for the second, weight-carrying capacity; and for the third, speed and comfort.

(c) **Points of General Ground Organisation.**

In order to maintain aircraft in the air, it is necessary to perfect as far as possible the organisation on the ground. There are at present in Great Britain 53 civil, official and privately owned aerodromes and 53 service aerodromes, available for civil aircraft in emergency, and arrangements are proceeding for the provision of landing facilities for seaplanes at a number of British ports and at French, Dutch and Belgian ports where Continental traffic is concerned. The new Air Navigation Bill gives power to local authorities to acquire and maintain aerodromes.

The nearer to centres of population aerodromes are situated, the greater the saving in time that is effected. Under present conditions landing grounds for aeroplanes are necessarily located some distance outside large towns, but we are trying to devise a scheme by which large rivers flowing through towns may be

used for landing seaplanes and amphibians, thus saving the relatively long journey to the aerodrome. Negotiations are in progress from which it is hoped that the Thames may be used for this purpose.

A problem of considerable difficulty is the ground organisation for night flying. It is obvious that as soon as night flying is practicable the flying capacity of the aeroplane will be doubled. Aerial lighthouses have been in operation for some months at Biggin Hill and Croydon, another will shortly be located at Lympne, and a third between London and Folkestone. Other civil Government aerodromes will be equipped as soon as night flying is practicable. You may say night flying *is* practicable. It was done during the war. But it is regularity which one wants to obtain. Night flying was carried out all the latter half of the war, but we have not reached the regularity necessary for a postal service, and a great deal of work has to be done to secure it. Permanent electric landing lights and lights marking buildings are being installed, and experiments are being made in the use of a searchlight for showing up obstructions on the aerodrome, the illumination of wireless towers and flood lights.

Another important factor in the organisation of air navigation by night, and in fog or mist, is the installation of an efficient wireless direction finding and wireless telephonic system. The direction finding apparatus installed at Croydon enables aircraft to correct their course at night, or in thick weather, and a machine thus equipped with directional wireless can ask for and check its bearings as often as necessary. An interesting instance of the value of wireless telephony was afforded recently when an aeroplane with 10 passengers on board which was forced to land at St. Inglevert after dark was able to ask for landing lights from the air.

While on the subject of Navigation, I may point out the necessity for the continual improvement of all forms of navigating instruments. It is safer, in many circumstances, for pilots to fly by compass than by the ground, and they must train themselves to work by compass to a much greater extent than they do to-day. By arrangements made with the Society of British Aircraft Constructors, all compasses used by passenger and goods aircraft are to be certified by the Admiralty compass observatory, and a compass-swinging base has been constructed at the Croydon aerodrome.

(d) Meteorology.

The safety and regularity of air services are largely dependent upon accurate meteorological reports and forecasts, which give the pilots confidence and enable them to circumvent adverse weather. The forecast service of the Meteorological Office in the Department of Civil Aviation issues hourly reports and short period forecasts for the requirements of the moment; it issues, four times daily, forecasts covering 24 hours to assist in making arrangements beforehand, and it issues synoptic messages which give a birds-eye view of the weather conditions over the whole country.

Collective reports are issued hourly by W/T from Croydon Aerodrome, and copies are distributed to air transport companies and to others concerned. As a result of international agreement, similar reports are issued at Paris, Brussels and Amsterdam.

The organisation of the system of local centres, specially charged with the distribution of information, was commenced towards the end of 1919, three of which are primarily concerned with the provision of reports and forecasts for the London-Paris-Brussels-Amsterdam services. For points along these routes information is supplied on the surface wind and the wind at 2,000ft., on the amount and height of any low cloud, on the visibility and the prevailing weather, and, for seaplanes, on the state of the sea.

A knowledge of the upper air is of fundamental importance in the preparation of accurate forecasts and the use of aeroplanes and pilot balloons for determining the conditions above the surface of the earth has become a regular part of observational work.

The introduction of wireless telegraphy and its wide adoption by the mercantile marines of all countries, has also provided means for placing at the disposal of the meteorologist the observations over the sea for use in the preparation of forecasts, and for the guidance of flights over long stretches of open water, such as those in contemplation to the Scandinavian States. The equipment of lightships with wireless may in the future provide further assistance in this direction.

A feature of meteorology which is often overlooked is its economic value. By making use of a knowledge of the wind at different heights, aircraft can complete journeys more quickly than would otherwise be possible, and can thereby save their own fuel and their passengers' time. This will be specially useful in the tropics, where the regularity of the surface winds has its counterpart in the upper air, but even in Europe timetables can be drawn up with due attention to the favourable or unfavourable effect of prevailing winds.

(e) Economic and Financial Factors.

I will only touch here upon a few of the main features of the economic and financial aspect of civil aviation.

Speed must be paid for, and for some time to come the charges for air transport must be higher than those for other forms of transport. On the other hand, from the point of view of the public, the present charges are undoubtedly high, and it is an open question whether commercial services will materially increase the volume of goods and passengers carried until a reduction in price can be effected. It is the old problem, whether to reduce rates to increase traffic, or to wait for increased traffic to reduce rates. It is, however, very difficult to estimate costs at the present stage of development when the volume of permanent traffic and the cost of depreciation over long periods are still undetermined factors.

A severe handicap to the reduction of rates is the rising price of petrol fuel, and to place aviation on a firmer economic basis, we must discover a fuel which, concurrently with ensuring in the interests of safety the least chance of inflammability, gives the greatest possible power for the smallest possible consumption, and which is sufficiently light to allow of a considerable reduction in the weight of an aircraft load, especially on long journeys. Concurrently with the improvement of fuel, the engine must be developed so as to ensure its most economic use. It is quite possible we may eventually have to replace the petrol by the steam engine.

The problem of State assistance figures very largely in commercial aviation. The French have devised a liberal subsidy scheme which consists of payments for amortisement and upkeep, the crew, weight carried and the military value of the machine. Though it is stated that the subsidy will be granted to "legally constituted air navigation Companies carrying out regular services of public value," the criticism might be made that its practical effect is to give financial assistance to any Company maintaining machines in the air without sufficient regard to the value of the work done, or the commercial utility of the machine employed. In fact, a fourth part of the subsidy encourages machines of military utility, and therefore tends to counteract the development of a purely commercial type.

It is to be noted that the Swedish and German Governments are now granting subsidies to certain air transport concerns.

In England, on the other hand, the State provides indirect assistance by assuming responsibility for the organisation of aerodromes, wireless and meteorological services, by the adjustment of international questions, by research and experiments.

British policy is based on the theory that new industries, in order to encourage a healthy growth, must be self-supporting, and is therefore traditionally opposed to giving them direct financial assistance.

You will remember, however, that the Advisory Committee on Civil Aviation, in their Report, came to the conclusion that in spite of the indirect assistance provided, the development of civil aviation might stop short.

The scheme we recommend differed from the French in that the amount of the individual grants to transport companies is conditional on the regularity of the service and proportional to the actual amount of income received from the public using the service. 25 per cent. of the total certified gross revenue was suggested in that Report.

The last subject which I shall touch on under this heading of finance and economy is insurance. Under modern conditions insurance is closely interwoven with all human concerns to which any element of risk attaches, and every country interested in aviation is endeavouring to work out a sound and equitable insurance scheme. In France a Consortium of Insurance Companies has been formed and insurance, for which a detailed scheme has been drawn up, is being made compulsory by the State. The French subsidy scheme involves considerable supervision of aviation Companies by the State, and this may tend to State control of insurance.

Aviation insurance has also been actively taken up by the Scandinavian Insurance Pool, which consists of 89 affiliated Companies, and aims at becoming the Lloyds of the aircraft world.

In England our policy is to encourage insurance as far as possible to take its normal course. At present, however, Insurance Companies are handicapped by a relatively small field of operation and lack of machinery and experience. At this stage, therefore, the responsibility for inspections, licensing, certificates, etc., devolves entirely upon the State. It is hoped, however, that with the expansion of air transport and greater experience, the insurance world will assume a great deal of the work of inspection at present carried out by the State, and that Aviation Companies will realise that it is advantageous to insure and to conform to safety regulations laid down for insurance.

(f) Carriage of Mails.

Without minimising the importance of goods and passenger traffic by air, in my opinion the carriage of mails is the basis on which commercial aviation must at present develop. Aircraft has revolutionised the speed of intercommunication by letter; and banks and financial houses are beginning to realise that large savings can be made by utilising air mails for the transaction of business. We should approach the question by considering not what mails can but what mails cannot be carried by air. The area of the British Isles is not very favourable for an extensive air mail service, which can only operate by day, since by the existing means of transport mails are carried during the out-of-business hours and can generally reach their destination in a night. This again points to the necessity for night flying.

On the air services to the Continent, on the other hand, a great saving in time is effected, and I should like to see a very material increase in the amount of mails thus carried, with the ultimate result of the carriage of all mails by the certified Continental air services at normal rates.

It is only by large experiments such as are being made by the Post Office authorities in the United States, where all mails are carried at the normal postage fee on the routes in operation by aircraft, that useful experience can be gained.

III. SUGGESTIONS FOR FUTURE DEVELOPMENT OF AIR SERVICES.

In urging the establishment of air services within these islands, we must face the fact that commercial aviation cannot enter into competition by day only with an efficient day and night express railway service, such as is to be found running north and south in England, though possible exceptions might include amphibian services between London and Dublin, or between Glasgow and Belfast. Flying boats could alight in Belfast Harbour and on the Clyde at Glasgow.

In Continental countries also air transport has to compete against railway systems, but the distances between centres of population and industry are more suited to the operation of air services and the railway network is less perfect than in England.

The position of Germany and Austria is very favourable to the development of air services. Berlin is within a 350-mile radius of Copenhagen, Cologne, Munich, Vienna and Warsaw, while Vienna is in an advantageous situation as the junction for a south European system extending to the Balkan States and the Near East. In the United States the distances are such that aeroplanes, flying by day only, can in many cases effect considerable saving of time.

The insular position of the United Kingdom, on the other hand, is by no means unfavourable to the establishment of air services to the Continent, whereby the sea passage and the loss of time entailed in changing from ship to train can be saved. Until night flying is safer and longer distances can be flown continuously, we must ensure the maintenance of the existing services to the Continent and promote others, such as to the Scandinavian countries and the North German ports, and, I think, to Spain and Portugal.

We have, however, to consider commercial aviation, not only from the Continental but from the Imperial point of view. Here we have the long distances favourable to aircraft, but England is detached, either by the ocean or foreign territory, from the nearest Dominion or Possession. In the one case the range is too great for aeroplanes, in the other they are dependent on foreign landing grounds. The key routes in the Imperial system are those from England to Egypt, and Egypt to India, and we should see whether the airship is capable of running a commercial day and night service on the former. Even if the airship is successful, we must still develop the long-distance, weight-carrying aeroplane, capable of carrying economically 50 to 100 passengers, or their equivalent, and undertaking the trans-Mediterranean journey, with Malta as a stopping-place.

When the political difficulties of Syria and Mesopotamia have somewhat subsided, we shall be able to complete the preliminary organisation of the route from Egypt to India which has recently been checked. This route has the advantages of good climatic conditions, considerable strategic importance, great saving of time and utility for the carriage of mails, and is relatively easy to operate.

The onus of linking-up the Empire by air must not rest upon Great Britain alone. Each Dominion and Colony must form its own nucleus of air development, and thus help gradually to build up the complete system.

There are within the various countries of the Empire considerable opportunities of practical development, and I must touch on a few of these. At present the West Indies are suffering from the lack of inter-island communication, both for mails and passengers, and this can be partially rectified by an air service for the Leeward, the Windward Islands and the Bahamas, and between the Bahamas and the American Continent, where an American Company has actually conducted a service. I am glad to say that the Bermuda and West Atlantic Aviation Company is interesting itself in this project.

Large rivers are adaptable to flying boat services, especially as they have

the great advantage of visibility by night, and the consideration of a project for such a service on the Nile was only given up owing to the disturbances in Egypt.

A practical scheme is also under consideration for an air service from Melbourne to Sydney, Adelaide and Hobart in Tasmania. The distances between the various stopping-places are not so great as to overtask the capacity of modern aircraft, and should afford an excellent criterion of the value of aircraft as a mail and passenger carrier.

These instances will, I hope, afford some indication of the various methods whereby development may be assisted.

The progressive design of aircraft is the pivot upon which, during this period of experiment, aviation, both Service and Civil, turns, but designing staffs can no longer be maintained by constructors unless there are opportunities for the practical application of their labours on a remunerative basis. This opportunity is offered by the new air transport industry with its unknown factors and its ever-present need for improvement in safety, reliability, speed and comfort. I do not know if it is sufficiently widely recognised how great are the difficulties against which air construction and transport firms have to contend, the intricate scientific problems, the correct calculation of economic results, the general financial depression and not least the lack of sufficient public support.

Some firms have already dropped out of the race, but I hope that with greater appreciation of the potentialities and increased knowledge of the achievements of commercial aviation, there will be an outspoken demand from the nation as a whole for the maintenance and expansion at all costs of civil air transport as part of our national policy.

I thank you for the opportunity you have given me of addressing you tonight, and remembering the splendid contribution made by your Society to the science of aviation, I feel confident that collectively and individually you will leave nothing undone to ensure the success of civil aviation.

DISCUSSION.

The CHAIRMAN said the Paper was full of interest and raised many points which gave much food for thought. He would ask Lord Montagu of Beaulieu to open the discussion.

The Right Hon. LORD MONTAGU OF BEAULIEU said Sir Frederick Sykes had a special claim to speak on the subject, as he was not only a practical pilot himself but had been in charge of Civil Aviation some time, and possessed very valuable qualities in his present office, the qualities of imagination and persistence, which were so necessary to the development of anything new. He hoped Mr. Illingworth was going to do what he could for civil aviation. He knew the Government had many claims upon it, but he thought it was to the Postmaster-General they must look for material assistance in the development of commercial aviation at the present time. By the Postmaster-General employing aircraft on definite routes, preferably long-distance routes, a great step forward would be achieved. If it were a question whether they paid or not, he would remind his hearers that in the early days of fast coaches, or the early railway trains, or the first mails carried by sea, they probably did not pay. All mail services had to be sufficiently used before they paid. Every development of that kind must have a certain amount of assistance, either from the public or the State at its beginning, and he hoped the State would help in this case. What Sir Frederick Sykes had said about inter-European services reminded him that in France the other day he saw an ambitious programme put forward for the development of the aerial service—more ambitious than they had seen on the Lecturer's map. Sir F. Sykes was right in saying that places like Vienna, Berlin, and, to some extent, Paris, were

better situated for the development of civil aviation than we were at a dead-end in the United Kingdom. Perhaps the most favourably situated country was Egypt, through which most of the mails to the East and to Africa would eventually pass, but, at the same time, much could be done in this country and in air mails to and from London, which, after all, was the chief city in the world and probably the most active and wealthy, with all the different Continental centres. He had no doubt, in a few years, they would see them so connected. He thought Sir Frederick Sykes' figures showed that the impression should be corrected in the public mind that aviation was going back. Aviation was advancing, but not very fast at the present time. It could not be expected to advance till the end of the reaction after the stimulus of war. He was glad the Lecturer had faith in aviation as a practical means of conveyance and that there would be mails carried by them round the world. They knew that in Sir Frederick Sykes' hands the future of civil aviation was safe.

Mr. F. HANDLEY PAGE said the figures for aerial mails given by the Lecturer were, he thought, somewhat misleading, because, although they saw that 7,000 odd letters were carried in the month of August, one hardly realised that that only meant a total of about 40lbs. per day. From the point of view of an aerial transport company, the carrying of 40lbs. a day was not exactly a remunerative undertaking. He disagreed with other speakers who looked to the future in mail work. Every passenger who paid for his carriage paid for, roughly speaking, 180lbs. weight of matter, good bad, or indifferent, whereas every letter that travelled was only from half an ounce to an ounce in weight. Getting traffic for the air service was only a matter of persuading people to travel by it or use it, and one could much more easily persuade one man of 180lbs. weight to travel by it than persuade 5,000 odd people to use the air mail service, which would only mean the equivalent weight. Up to the present it had been found easier to persuade passengers to travel than to persuade them to use the service as a mail service. It was purely a question of developing aerial transport by getting people to travel on the service at a price which was more than the operating cost. Provided that margin was big enough, so that the returns to the investing public were large enough, there would be a big boom in air transport as the world would see that they could make something by putting their money on air transport. That was the determining factor—the question of the balance sheet.

In Great Britain and in Europe there were not as great opportunities for development as in the United States. The distance from the eastern to the western coast of the United States was as great as from this country to the other side of Russia or to Cairo. In the United States they were one people, speaking one language and with one customs system and one currency, and they had a very big mail order business which required quick delivery—conditions essentially suitable for air transport. In Europe, however, between Great Britain and the other side of Russia three or four countries had to be passed through, with customs and currency difficulties and different languages spoken. The consequence was that apparently traffic should be more easily developed in the U.S.A. than in Europe.

In England also we were at a great disadvantage compared with continental places. For instance, suppose instead of having our headquarters in London we had it in Paris, we could run a service from London to Marseilles with the same machines and without changing our passengers, and we should be able to pick up and set down passengers en route. But with headquarters in London an English company could not do inter-coastal traffic, that is, pick up in Paris or other French towns and set down in France. That was a privilege reserved to the nationals of the country. In England we were at a terminus, but a company located in France could come over to London and run with French machines a service from London to Paris, London to Brussels, and London to Amsterdam, and do everything an English company did here. The only restriction would be that they would not

be allowed to fly from London to Manchester or Glasgow, but the possibilities of traffic with those places, owing to the good railway system we had in this country, were remote. From the point of view, therefore, of purely supplying a better service to the public, and therefore presumably improving one's balance sheet, it would be better for an English company to have its headquarters at Paris or Brussels. That was where Government assistance was most necessary. There should be some inducement for air transport companies to stay in this country, some inducement to balance the economic advantages of going abroad. Otherwise one could clearly see that the best course, apart from Excess Profits Duty (which at the moment did not arise in aircraft transport), was to move out of this country and have one's headquarters on the Continent. It would be a great pity if that happened because this side should be the commencing point of great Imperial air routes. Whilst, however, it was nice to talk about Imperial air routes and patriotism and running a line from Great Britain, and so forth, in the long run it was generally the pocket that told, and unless there was some balancing advantage he could see a decided economic advantage in moving to the Continent.

Sir Frederick Sykes had spoken about improving types of machines and the advance that might probably be made in aircraft construction. There were two sides in which advances might be made. One was making the aircraft itself more efficient, so that with a given horse-power greater speed would be attained or a greater load carried. Progress in that direction might lead to cutting down the running cost by a third or even a half of their present rates. But apart from that, there was the question of improving the power plant and utilising it better than it was done to-day. It was all very well to design a machine for efficient working when it was in the air, but there was also the problem of getting it into the air. It was an analogous problem to that of a motor car, and the difference between a fast running car and a motor lorry. A gear-box was not necessary in the fast car. One could slip the clutch and very quickly reach top speed. Most of the running was done at the top speed, so that change of speed was not necessary. But with the lorry one must have a gear-box to be able to start and to drag heavy loads up and down hill. In aircraft during the war high performance was required and not high economy, and the question of the utilisation of power was not such an important feature. It was only when they came to commercial working that the utilisation of power became very important. The consequent problem seemed to him to be the utilisation of the power more efficiently from the engine in getting up into the air. A possible solution would be a propeller 20ft. in diameter to get off the ground and 10ft. when in the air. That seemed necessary if they were to have a short run along the ground and a quick rise in the air, but once in the air the most successful aircraft would be that which was cheapest to run. It was a question of having a variable power effort in the machine, but he should think it was within the scope of the inventive genius of the people who had been connected with aircraft, and had now gone into other industries that they had found more remunerative. He thought those two problems were those upon which aircraft designers should concentrate their attention. It was probable that improvement would be made through a gradual development of existing designs and applications of known principles, rather than by radical advances in designs.

Mr. A. E. L. Chorlton (Sir Wm. Beardmore and Co.) said, with regard to the engine point of view, Sir Frederick Sykes began by comparing the light-weight engine running at a lower rating with that of the heavier engine running at standard rating, and he desired someone to carry the comparison further in order to arrive at, if possible, some conclusion as to which was the right policy to follow. He had given a great deal of thought to the question, but what was first necessary was to obtain from transport companies and experts like Mr. Handley Page some exact data from practical working. He thought that if they had readily accessible statistics, which gave the comparative cost value of the engine—the power cost in running the place, it should not be very difficult to decide which type to adopt.

The heavy engine was more economical. Therefore, if it were shown that the obvious thing to do was to save petrol, then it was best to go for the economical and heavy engine, securing increased reliability, but it must be realised at a sacrifice in paying load. To provide for the conditions Mr. Handley Page set out, that was considerably extra power in starting and landing and for special occasions and at other times greatly reduced power, then probably an engine which would develop at the ground increased powers by running up in speed, which, with a variable pitch propeller, would meet the case. Such an engine would probably be a heavy one, because it must carry full compression at the ground and also when it got up into the air, the full compression must be retained for the purpose of economy. In the late official trials that had been mentioned it was remarkable that, looking at them without any predisposition to consider them aeroplane trials, one got the impression that they were really engine trials. The results were graded down according to the weights of the engines, *i.e.*, the lightest engine per b.h.p. won the prize. In that sense they might be considered fortunate—or unfortunate—if applied to aviation. He considered that they had gone no further than that. The light-weight engine was attractive to a designer, but until statistics were given as to the relative values of economies of fuel and the values of power to get off the ground, one would be unable to decide which type was to be preferred.

Undoubtedly another governing factor in the selection of type of engine was length of journey. The shorter the journey the less important was economy and the more important light-weight per b.h.p., and probably this would eventually be the governing condition for use of the two types, *i.e.*, distance to be flown.

Commander EDWARDS hoped they would get some particulars of what airships had done in this service. Aeroplanes had to land where airships had not. They dropped the mails and could get rid of passengers by means of ladders to the ground. As Mr. Handley Page pointed out, London was a terminus for aeroplanes, but from the airship point of view it was the hub of the universe. Airships crossed the Atlantic, and a big passenger, mails and freight trade with America would pass through this island. He thought that the Aeronautical Society or some other Society should put the matter up to the League of Nations. As a first step it would be perfectly feasible, and was an economical thing to establish an airship service from London to Paris, Rome, Athens and Constantinople, running day and night, and that would be the proper way for passengers and mails to go. Aeroplanes could take the goods and letters from those airship centres to the local distributing centres.

The CHAIRMAN said as the Post Office had been mentioned he would say a word or two. He did not entirely agree with the Lecturer when he said the future depended entirely on the post. He (the Chairman) thought the post would always be a very auxiliary sort of cargo for aeroplanes or airships. The main thing would be the carriage of goods and passengers. Railways or ships would not be run on mails alone, even if the parcel post was included. It was the passengers and goods really which paid, and the mails were a very subsidiary sort of thing. However, he was glad to see that the air mails were increasing and getting more regular and reliable. Unfortunately, the distances they were running now were rather short, but the results of the service to Amsterdam, which was much further than Paris, showed that the distance was the great thing, as the time saved on the Amsterdam journey was more important. In other respects also aeronautics was improving. The performance of the machines was much better than it used to be. He remembered the first meeting in France at Reims. If an aeroplane there flew a hundred metres everybody had hysterics almost. The progress made had been great, but there was still a long way to go, and he was sure the British makers would lead in civil aviation as they did in war, and he did not think it would be in the interests of the industry to have it looked at by the Government. Government subsidies meant Government control, and Government

control of any industry meant the quickest and surest road to the Bankruptcy Court. He thought if aircraft builders and designers had a short experience of that they would give anything to be out of it. He was sure the thanks of everybody were due to Sir Frederick Sykes for his interesting Paper. He hoped some practical use would come of it and that it would be some lead to the Conference which was to take place at the Guildhall the following week. He proposed a hearty vote of thanks to Sir Frederick Sykes.

Major-General R. M. RUCK moved a vote of thanks to Mr. Illingworth for presiding. He hoped he would not consider that the gratitude of the members was entirely due to favours to come. They desired to thank him for his presence at that meeting.

Sir FREDERICK SYKES said that the discussion had raised many points of interest. He believed that it would be some time until sufficient passengers and goods were forthcoming to make air transport develop on the scale which was necessary. He thought that in the meantime the best way to keep air transport alive was for *all* mails on certain routes to be carried by properly certified companies. This would represent that instead of the one machine carrying only 40lbs. mentioned by Mr. Handley Page, some four or five large machine loads per day on each line—a very different matter. The public as a whole would undoubtedly soon learn to appreciate the value, once demonstrated, of a quicker service to the Continent. It was the present uncertainty of traffic which was largely responsible for keeping fares high.

As it was unlikely that the G.P.O. would agree immediately to send all mails on certain services by air, he was in favour of granting direct assistance to external services, as a temporary measure, on the lines of the report of the Advisory Committee, but it would be uneconomic from a purely business point of view to bolster up internal air services unless they were found to be of practical utility, which, for reasons already stated, he doubted. At present it was the Continental services which showed the best prospect of financial success and were susceptible of more extensive development.

He was glad Mr. Handley Page appreciated the difficulties connected with flying over foreign states. The international arrangements necessary for organising the Continental services and for flights to the Continent had taken up a great deal of the Air Ministry's time and thought, but the result was that international relations were on a much better working basis.

Mr. Chorlton's remarks were very suggestive, and he thought that with perseverance and research a more economic engine would be evolved.

One word about airships; their value was fully appreciated and it was undoubtedly true that their power of keeping in the air for many hours, or even days, and of flying by night were a great advantage. It was hoped that experiments would soon be carried out to demonstrate more fully than hitherto their value for commercial services.

A FEW REMARKS CONCERNING SOME FUNDAMENTALS OF THE THEORY OF BLADE-SCREWS.

BY DR. GEORGE DE BOTHEZAT.

The fundamentals of the blade-screw theory have been lately the subject of numerous discussions. Most of these discussions are the result of misunderstandings arising from the fact that the fundamental conceptions and quantities involved in the subject are left without sufficient definitions. The blade-screw problem is very complex. Its study requires the use of many new conceptions and physical laws in generalised form. For the last reason, special attention must be paid to their exact statements. The following remarks are intended to bring attention to some of the fundamentals of the subject which seem to be the main source of the misunderstandings which are the most widespread at the present time. All the considerations that follow are quite general; they take place for any blade-screw, but it is the propulsive blade-screw or propeller that we will chiefly have in view here.

I.—CONCERNING THE MEAN VELOCITIES USED IN BLADE-SCREW THEORY.

Let us consider a blade-screw having n blades, making N revolutions per second, on which is directed a uniform flow of V mt./sec. parallel to its axis. As it is well known, the flow velocities in the slipstream are periodical functions of time as well as space co-ordinates. More exactly, this means that *at a given point* of the slipstream, the *instantaneous values* of the flow velocity are periodical functions of time, the frequency being equal to nN (that is, the number of blades multiplied by the number of revolutions) and at a *given moment* the *instantaneous values* of the flow velocities, at points situated in a plane perpendicular to the propeller axis and at equal distances r from the last, are periodical functions of space, the space period being $2\pi r/n$. Let us now imagine that we begin to increase the number of blades of our propeller in such a way that the propeller gives us identically the same thrust of Q klg. and torque of C klg. mt. for the same number of revolutions N and velocity V of the flow directed on the blade-screw. Under such conditions the time frequency nN will increase and the space period $2\pi r/n$ decrease and in the limiting case of an infinite number of blades, the slipstream (for the same N and V) will cease to be a periodical flow and will become a steady flow. This means that the flow velocities at equidistant points from the blade-screw axis will have the same values in time as well as in space.

When in the blade-screw theory, we speak of the *mean velocities* of the slipstream, it is the velocities produced by this *equivalent blade-screw*, of infinite number of blades producing the same thrust Q and torque C (at the same values of N and V) as the blade-screw, that are meant.

Let us find the relations between the instantaneous flow velocities as just defined. My intention is just to show the nature of the question. I will limit myself to the consideration of the axial components of the flow velocities alone. Let us consider, in the narrowest section behind a propeller, an annulus $\Delta S''$ of radius r'' and width $\Delta r''$ and designate by $V + v_e''$ the *mean* axial velocity component in the slipstream, v_e'' being the total additional mean velocity communicated to the fluid that has crossed the propeller. Applying the momentum theorem, we will see that the partial thrust ΔQ that corresponds to the annulus considered is equal to

$$\Delta Q = \delta \Delta S'' (V + v_e'') v_e''$$

where δ is the fluid density. Let us now designate by v_i'' the corresponding

instantaneous velocity values. For the calculation of the partial thrust ΔQ, which is the axial component of the blades fluid resistance, we can refer the momentum theorem to a system of axes rotating with the propeller; that is, consider the whole phenomenon from the standpoint of an observer sitting on the propeller blades. For such an observer the flow around the propeller will appear as steady and for the value of the partial thrust ΔQ he will find

$$\Delta Q = \int_0^{2\pi} \delta r'' \Delta r'' d\phi \, (V + v_i'') \, v_i''$$

where $d\phi$ is the infinitely small angle between two radii of the narrowest section S'' of the slipstream.

By definition of the mean velocities we must have

$$\delta 2\pi r'' \Delta r'' \, (V + v_e'') \, v_e'' = \int_0^{2\pi} \delta r'' \Delta r'' \, (V + v_i'') \, v_i'' d\phi$$

or

$$(V + v_e'') \, v_e'' = (1/2\pi) \int_0^{2\pi} (V + v_i'') \, v_i'' d\phi$$

or finally

$$V v_e'' + v_e''^2 = (V/2\pi) \int_0^{2\pi} v_i'' d\phi + (1/2\pi) \int_0^{2\pi} v_i''^2 d\phi$$

This last relation shows us that the mean slip velocity v_e'' has a value larger than the arithmetical mean of the v_i''; but smaller than the effective value (square root of the mean squares) of the same v_i''. Only for the case of work of the propeller at fixed point with $V = 0$, do we find v_e'' to be equal to the effective value of the v_i''. I will not go into any further details referring to this question. But what has been said is quite sufficient to convey clearly the reason why, when we want to verify experimentally the theoretical ratio v_e''/v_e, where v_e is the mean slip velocity in the plane of the propeller rotation, we find values generally somewhat different from 2. The thing is, that measurements give quantities proportional to the square roots of

$$(1/2\pi) \int_0^{2\pi} (V + v_i)^2 \, d\phi \text{ and } (1/2\pi) \int_0^{2\pi} (V + v_i'')^2 \, d\phi$$

Values of slip velocities deduced from the two last expressions are somewhat different from v_e'' and v_e and in the ratio $v_e''/v_e = 2$ it is the mean values, as above defined, that are understood. Those who have made experimental verifications of the value of the ratio v_e''/v_e do not need to apologise for having made such investigations. It must only be clearly stated just what has been measured and what the theoretical ratio v_e''/v_e means. Without going into any further details, I will say that when experiments are interpreted in the light of the foregoing understanding, they show that the theoretical ratio $v_e''/v_e = 2$ is very closely verified.

The only factor that can produce a departure of the ratio v_e''/v_e from its value 2 is the drop of pressure towards the axis of the slipstream produced by the race rotation. For propulsive blade-screws, this departure is less than one per cent. For blade-screws working at fixed point, it can reach more important

values and in some cases has to be taken into account. In Note VI. of my blade-screw investigations,* I have shown in general outlines how the departure of the ratio v_e''/v_e from its theoretical value 2 can be estimated. It is by similar consideration that it can be decided upon the mean value of the race rotation.

II.—THE EXACT INTERPRETATION OF THE DRZEWIECKI STROBOMETRIC EXPERIMENT.

I must sincerely say at the outset that I hardly understand how some people managed to conclude that the Drzewiecki strobometric experiment has shown the absence of inflow, when this experiment on the contrary shows that, even in the limiting case of a one-blade propeller tested by Drzewiecki, there was undeniably an inflow.

Let us first make quite clear what we mean when we say that an aerofoil gives us a resistance

$$R = k_1 \delta A W^2$$

when disposed in a uniform flow of speed W. The speed W here involved is the speed of the fluid current far in front of the aerofoil where the flow is still uniform. I will later give an analytical definition of this speed W. If we will consider the local velocities around the aerofoil, we will find them, as well known, different at different points. Above the aerofoil the local velocities are greater than W, on account of the drop of pressure and below the aerofoil the local velocities are less than W, on account of the increase of pressure. If, for some reason, we should not know the value of the flow speed W and should only know the values of the local velocities around the aerofoil, we could, on account of the above statement, only conclude that the velocity of the flow directed on the aerofoil is greater than the smallest local velocity observed and less than the greatest local velocity observed. It is evident that in no case may we conclude that the flow velocity is equal to the smallest local velocity observed for an aerofoil giving lift. The foregoing also holds true more or less for the components of the local velocities and flow velocity along a given direction, because of the small angles of mutual inclination of these velocities.

Now, what did Drzewiecki find in his strobometric experiment? The smallest axial component of the local velocity was found to be equal to the wind tunnel speed. But this just shows that there was an inflow, because otherwise this smallest local velocity would have been less than the wind tunnel speed, as would be the case for an immobile aerofoil disposed in the wind tunnel.

The strobometric experiment of Drzewiecki simply shows, by the observation of the local velocities, that the rotating propeller, even in the limiting case of a single blade, produces a general inflow.

It is clear that all the conclusions drawn from the wrong interpretation of the Drzewiecki experiment will have to be dropped.

I will now go a little more into details concerning the physical nature of those conditions that require the existence of an inflow in the case of a *rotating propeller.*

III.—THE GENERALISED FORM OF THE FLUID RESISTANCE THAT WE MEET IN THE CASE OF THE BLADE-SCREW.

Let us cut the blades of a propeller by two concentric cylinders of radii r and $r + \Delta r$ and let us develop the sections thus obtained in a plane. We will then get the general picture of the annexed figure, in which the flow stream lines have been schematically represented, as they would appear to an observer sitting on

* "General Theory of Blade-Screws," by Dr. George de Bothezat, published in the Fourth Annual Report of the National Advisory Committee for Aeronautics, Washington, D.C., 1918.

the blades. It will be easy to see from the fact that only the fluid contained in the slipstream is involved in the phenomenon of work of a propeller; that to each blade section of width Δr corresponds a *finite mass of fluid* ΔM that flows past the considered section in the unit of time. On the figure we have delineated the fluid stream corresponding to each represented section by a thick line. It is the latter fact that constitutes the main difference between the condition of work of a blade section and that of an ordinary aerofoil. In the case of the blade section, the flow behind the blade section undergoes a *mean permanent deflection* for the whole mass ΔM; that is the relative flow velocity behind each blade section has a different value and direction from the one in front. Only when the radius r of the blade sections will be considered increasing up to infinity, the peripherical velocity being maintained the same, will we approach to the flow conditions around an ordinary aerofoil whose relative flow velocity in front and behind are the same. Exactly speaking, this means that for an ordinary aerofoil, the mean flow velocity variation referred to the whole fluid mass directed on the aerofoil (this mass is infinite) is infinitely small. In the case of a blade section, this velocity variation is finite on account of the fact that ΔM is finite. The same reason necessitates a general axial inflow in the case of a rotating propeller (which means an increase of axial momentum) because *otherwise there would be no thrust produced*, provided the principles of the Newtonian mechanics are accepted.* We thus meet, in the case of a blade section, with a more general case of fluid resistance. Each blade section is immersed in a fluid current, the velocity of which is changing in magnitude as well as direction along the current, and the flow behind the blade section has a value different from the one in front. Under such conditions, the only way to reach a definition of what we mean by the flow velocity to which the fluid resistance of a blade section has to be referred, is to define it by one of its fundamental properties. In the case of an ordinary aerofoil, the fundamental property of the speed W to which the resistance

$$R = k_1 \delta A W^2$$

is referred, is that

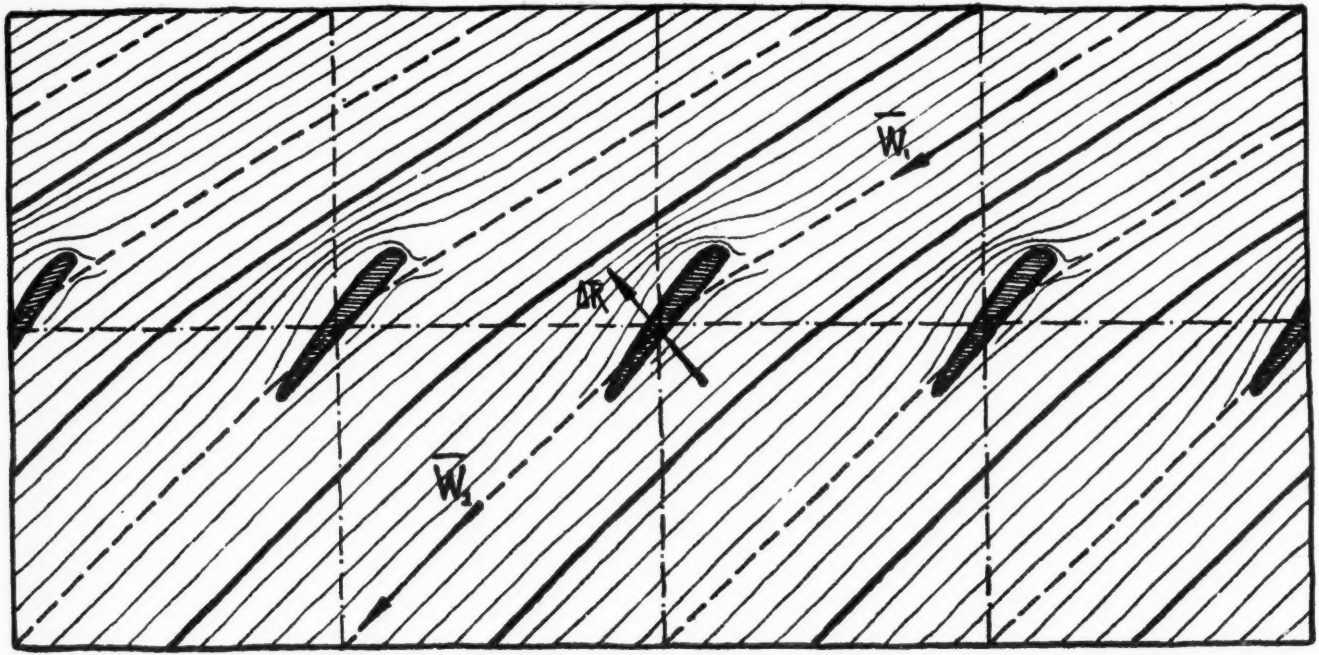
$$-RW\cos(R_1 W)$$

represents the work spent for the displacement of the aerofoil in the fluid. It is natural in the more general case of a blade section, to use just this relation for the definition of the speed to which the blade section resistance must be referred. I hardly see how any other standpoint could be adopted. It is just the definition which I have used in my blade-screw investigations (see p. 27 of my paper mentioned in the foregoing). We thus reach a generalisation of the ordinary law of fluid resistance for the case of a current with limited boundaries and variable velocity. It is easy to understand that in this more general case, the aerofoil resistance cannot depend alone upon the velocity in front, because for the same velocities in front there can be different velocities behind for different aerofoil shapes and the resistance must thus depend on the velocity behind as well as on the velocity in front. When the relative flow velocity to which the fluid resistance is referred is defined by the fundamental relation which states that

$$-RW\cos(R_1 W)$$

represents the work corresponding to the resistance R, it is easy to show that the

* Let us imagine that a fan, having only a *single* blade (the other blades may be supposed to have been broken off) is held in one's hand. If such fan will be brought into rotation it will produce a blowing action, experimentally easy to observe (and only accompanied by a disagreeable inertia effect resulting from the asymmetry of the rotating body). If now we will start to move this fan in the direction of its axis it is clear that its blowing action will not disappear, but will only be modified. We will just find ourselves in the conditions of the Drzewiecki experiment. With increasing translational velocity, the blowing action of the fan will decrease and for a certain value of this velocity the blowing action will disappear. Only at this moment will the thrust disappear. It is thus easy to understand that so far as our fan will give a thrust it will blow—this independently of its number of blades—and thus an inflow will exist.



Developed flow, past the blade sections at a certain distance from the propeller axis in the relative motion of the propeller towards the fluid.

velocity $\overline{W}$ is the geometrical mean of the velocity $\overline{W}_1$ in front and velocity W_2 behind.

$$\overline{W} = \tfrac{1}{2}(\overline{W}_1 + \overline{W}_2) \qquad \text{(geometrical sum)}$$

I will not enter further into a detailed discussion of this important question. I merely wish to state that as previously mentioned in my "General Theory of Blade Screws" (First Memoir) that no race rotation can take place in front of the propeller. But for the relative flow velocity W a race rotation rw has to be considered in order to satisfy the fundamental relation that

$$-\Delta R W \cos(\Delta R_1 W)$$

represents the work spent for the displacement of the considered blade section in the fluid. The race rotation rw has thus to be understood not as an actual inflow velocity, but as a virtual inflow velocity as defined above. It is in such a way that we must understand the flow velocity to which the fluid resistance of a blade section must be referred. It is the only possible way of reaching a definition without ambiguity, both as to the value of W and as to its angle of attack with reference to the blade.

In the so-called *Cascade method* of Mr. R. M. Wood, the existence of an inflow produced by the blade considered is denied and only inflow produced by the other blades is admitted. It is clear, after the above explanations, that such conception is without any foundations. We even now have in the Drzewiecki strobometric experiment, evidence opposing such conception. The fact that numerical calculations seem to verify this assumption indicates only that in particular conditions, a certain approximation can be reached by this method. With such a statement of the question, however, the results have no generality and no well established definitions are put forward. On the contrary, when the fluid resistance of a blade section is referred to the velocity

$$\overline{W} = \tfrac{1}{2}(\overline{W}_1 + \overline{W}_2)$$

an important generalisation of the fluid resistance law

$$\Delta R = k_1 \delta \Delta A W^2$$

is reached, which satisfies the fundamental condition that

$$-\Delta R W \cos(\Delta R_1 W)$$

represents the work corresponding to the resistance ΔR.

I hope that these explanations, although very brief, will permit a full understanding of the real nature of the fundamental questions involved and make clear the real meaning of the expressions of the values of the slip and race velocities, which are for the first time established in my blade-screw investigations. The values I have given are explicit values only in function of the blade sections dimensions and their coefficients of fluid resistance.

Finally, I desire to remind those who may use some of the results or suggestions published in this note, that they are obliged to quote the source of their information, if they only care for the ethics of relations among investigators. I regret that I am forced to make the last statement here, but since the publication of the First Memoir of my blade-screw investigations (Russian edition out of Press beginning 1917,* American edition out of Press beginning 1919) very generous use has been made by some authors of many of my fundamental results and conceptions (including even the reproduction of parts of my figures, with the simple camouflage of change of scale and a few additions) and I feel myself rather shocked by such liberty, especially when practised at such tragical moments of the Russian situation.

GEORGE DE BOTHEZAT.

Dayton, Ohio, U.S.A.,
September 21, 1920.

* Several private translations of which were used in London, since 1918.

CORRESPONDENCE.

To the Editor of the AERONAUTICAL JOURNAL.

"THE DESIGN OF SPARS WITH OFFSET PIN JOINTS."

DEAR SIR,—This most interesting Paper suggests the following remarks :—

Further advantages of the method.—The symmetry of bending moment in each bay gives the best case for shear. The greatest shear is exactly half the load on the bay, which is the lowest value possible, and it occurs at both ends.

Any uncertainty as to wing tip effect or local variation of wing section is confined to one bay and does not vitiate the calculations for the rest of the spar.

Small modifications suggested.—On each side of a joint the spar must be left solid. It is the stress where the full spindling begins, and not at the end of the bay, that we want to make equal to the maximum stress in the middle of the bay. Then in §11, L is the length of the spindled portion, and the length of the bay is greater by the amount left solid at the ends. The offset moment required is increased by this treatment.

Equation (M_{2n}) of §7 assumes that the drag and flying wires are equally offset; this is not essential. If the drag wire is centred, $P_n - P_{n+1}$ must be replaced by the component parallel to the spar of the flying wire tension.

Other considerations.—If the aerofoil is not deep enough to allow the required offset, we cannot get the ideal distribution of moment, and the best that remains may be an unsymmetrical arrangement which sacrifices much of the compactness and directness of §4 and 11. A continued beam may come closer to the ideal than the most offset pin joint practicable.

It is current practice to obtain equal stresses at three points by varying the lengths of solid spar at the two ends of the bay; but this can only be done if the maximum bending moment in the bay is greater than either fixing moment.

The fact that several points are stressed up to the elastic limit might arise from needless local stresses at some of the points and indicate bad design as well as good. The better criterion is total weight for strength. Concrete examples only can show whether the saving on the bays is partially discount or turned into a loss by additions to the fittings. There are not only pins and spar boxes to consider. Each pin-jointed section of a plane would have to be covered with fabric separately, involving duplicate wide ribs and end stiffeners. This might have some advantage, however, in a large aeroplane where the size of an individual plane section is decided by transport considerations.

Example.—The top front spar of the "Parnall Puffin" consists of an overhang, whose length is fixed by folding considerations, and two bays, with a pin joint on the neutral axis at the centre section, the special fitting here requiring a solid length of 7in. As designed the weight of the two bays is 10.4lbs.

The process of §11, with the assumption of 5in. solid on each side of the intermediate strut, indicates a possible saving of 1.2lbs. The bay spacing is unaltered; the offset for the intermediate pin is 4.11in. and for the inner pin 1.06in. Since the half depth of the aerofoil is 2.25in., the former offset would have to be considerably reduced, and the total saving of weight would probably be less than 1lb., which would not compensate for the losses entailed, in spite of the fact that

the gain on two bays is available to make up for the loss on only one joint. On the top rear spar the saving is .315lb., with an offset of 2.5in.

The theory may work out differently on a large aeroplane, and more examples would be very welcome.

Summary.—The saving of weight would have to be very clear to make up for the loss of rigidity and increased complexity of erection and rigging. The present suggestion is that, on small craft at any rate, where a hinge already exists the design may be definitely improved by offsetting the pin; but the gain would rarely warrant a pin joint that was not needed for other purposes.

Yours, etc.,

H. P. HUDSON.

REVIEWS.

Airscrews, in Theory and Experiment. By A. Fage, A.R.C.Sc., D.I.C.

Airscrew theory is at present in a state of flux. About 1913, or possibly earlier, the subject was to some extent "standardised" because its practical application in aeronautics had only just commenced. The theory, at that stage of its growth, was relatively a very simple one, and could be used for designing airscrews very easily. After a time, when aircraft designers had become accustomed to the use of the method, it was found that theory and practice did not agree even to a sufficient approximation for the requirements of the aeronautical engineer; according to certain people, theory and practice never agree under any circumstances. Accordingly "correction factors" (factors of ignorance) were introduced, drawn from test results on the propellers used on aircraft. This constituted perhaps the first modification of the theory due to S. Drzewiecki, and published by him in 1892.

Later, wind-channel research at the N.P.L. showed that the original theory left much to be desired. In September, 1916, Mr. A. Fage and his colleagues at the N.P.L. evolved a new theory, since known as the "inflow theory," which attempted more closely to approximate to the real conditions. Test figures showed that the new theory had achieved its object, although a small discrepancy still remained between the calculated and experimental results.

Some years later another method of attacking the problem was evolved at the R.A.E. by McKinnon Wood and others. This is known as the "Multiplane Interference Theory," and is related to experiments carried out on a "cascade" of model aerofoils, thereby mimicking very closely the real conditions under which any propeller blade is working. Before this, however, controversy had raged round the ideas underlying the "inflow theory," it being contended that the whole method was based upon an inconsistent process of thought and that there could not, under any conceivable circumstances, exist any "inflow" other than that due to blade interference. This latter contention is now known and accepted as rigidly true. But, because this is without doubt perfectly true, it does not follow that therefore the original "inflow theory" was illogical and inconsistent. As an empirical theory, and, incidentally, the best theory possible at the time of its birth, it is perfectly rational. The real objection to the "inflow theory" is to be found in the fact that, in order to get an equation, it was necessary to assume some value for the ratio inflow velocity/slip velocity at every radius along the blade length. The assumption made was this ratio was a *constant* for all radii, and herein lies the whole trouble. But this objection does not alter the fact that the method, rightly understood, is a logical, if empirical, one. The "cascade" experiments show that this ratio varies considerably along the blade length of any propeller. A clearer conception of the real state of affairs, which the "inflow theory" attempted to mimic, would have established the method upon a surer foundation, and as a probable result would have avoided the error into which the authors of the "inflow theory" fell by assuming a constant ratio for this quantity from a false analogy with the Froude theory of screw propulsion.

The difficulties encountered in the progressive evolution of airscrew theory multiply with each step forward. This is perhaps hardly surprising since as we advance nearer to the truth our outlook increases, and with it the complexity of the phenomena involved.

There are two other theories of the airscrew, with both of which Mr. Fage deals in his book—those of F. W. Lanchester and G. de Bothézat. The latter is similar in form to the "inflow theory," although more elaborate.

The volume under review may in general be said to embody a full and detailed description :—

(1) Of the airscrew theories at present in use, particularly the "Inflow Theory."

(2) Of the experimental methods by which airscrews, model and full size, are tested.

(3) The application of (1) and (2) to practice.

(2) requires the principle of dynamical similitude for an interpretation of the results of experiment. An account of this principle is given by the author. The author substantially adheres to his original theory—the "inflow theory"—when it is necessary to employ theoretical methods of solution for the various problems considered.

Such subjects as: Interference of an airscrew and an aeroplane, Tandem airscrews, The variable pitch airscrew, etc., etc., receive careful attention on both the theoretical and experimental sides. Airscrew stresses, and the vibrations of an airscrew, are very fully considered. A short discussion on Helicopters and Windmills completes the text. A list of Symbols, Bibliography, and Index are included. The illustrations throughout and the letterpress are excellent.

The book is not pre-eminently a book of airscrew *design;* rather is it concerned with an account of modern laboratory methods of research, together with the empirical theories used in co-ordinating the results of the experimental work. As such this work is probably the best extant in the English language. It necessarily embodies much of the work already published by the Advisory Committee for Aeronautics, with which some of us are already familiar.

The author is to be congratulated upon his latest work. M.A.S.R.

Principles and Practice of Air Navigation. By Lieut. J. E. Dumbleton, R.A.F. 163 pp. 12s. 6d. net. Crosby Lockwood & Son.

There was little need during the war to make any extensive use in the air of the methods of navigation which had long been practised at sea; what was done in this direction was what would now be regarded as being covered by the use of "pilotage" methods, *i.e.*, methods depending on the sight of the ground. The "dead reckoning" was, of course, kept—and in the case, particularly, of the anti-submarine air patrol exceedingly well kept—but astronomical methods of checking position were not used. It is only since the war that the science of air navigation has been studied in all its aspects, and in the interval very real progress has been made. Lieut. Dumbleton was at one time an instructor in air navigation at one of the schools of aeronautics, and his book is of much interest in showing the main part of the course of instruction. To be of use to those now studying the subject it would need to be supplemented by instruction in the more recent developments such as the gyro turn indicator, the newer types of bubble sextant and the various methods of reducing observations of heavenly bodies so as to enable "position lines" to be drawn on the chart.

The section of the book dealing with the taking of cross bearings is good and the method is one of real value in air work. Its value at sea is well known. A good deal of space is given to radius of action problems, but it scarcely seems likely that anyone approaching the subject for the first time would follow easily the exposition given. It is certainly capable of being put much more simply.

Some account is given of the principles of magnetism and of compass correction, but little or nothing on the various types of compass and their behaviour.

We think the book is an interesting one and it will surely prove of use. But when another edition is called for we hope the author will take the opportunity to bring it up to date.